Information Framing Effects in Biotechnology Communication – A Comparison between Logical-scientific and Narrative Information

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Abstract

This study explores information framing effects by comparing the effectiveness of using logical-scientific vs. narrative information to communicate about food biotechnology to consumers. An online survey was conducted in the summer of 2016 with 804 Canadian adults. Data were collected on attitudes towards food biotechnology and food choice behaviours. In particular, a choice experiment was included in the online survey to elicit preferences for diverse novel food attributes and technologies. Each respondent was randomly assigned to an information condition. A logical-scientific information condition about biotechnology was developed and written in a scientific style using the passive voice with generalized and impersonal language. In contrast, a narrative-style information condition about the technology was written in a more lively and vivid personal style. Results indicate that information about food biotechnology shown in different formats (logical-scientific vs. narrative) or being accessed by respondents in different manners (forced exposure or voluntary choice) can have differing impacts on perceptions and preferences. Compared with logical-scientific information, narratives and/or voluntary information access could help to reduce the opposition to biotechnology.

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1. Introduction

As the science behind agriculture and food production evolves very rapidly, explaining its benefits and risks to consumers can be challenging. The primary goal of science communication is to disseminate factual and unbiased knowledge and information, however, when communicating with consumers about novel food technologies (e.g., biotechnology), *how* the information is presented could be as important as *what* information is presented.

Logical-scientific language is required for conducting rigorous science research and disseminating knowledge in peer-reviewed scientific journals. Food scientists, researchers, and experts are trained to use logical-scientific language, however, non-expert consumers, as laypersons, tend to be exposed to information about science, especially food technologies, through mass and social media where narratives are used in order to develop appealing stories to compete for their audiences' attention. (Dahlstrom 2014).

This study explores information framing effects by comparing these two information formats – logical-scientific vs. narrative – to communicate about food biotechnology with consumers. In particular, we examine whether narratives (stories) about biotechnology result in consumer choice behaviours that are different compared to the use of logical-scientific information.

Previous studies reveal significant information framing effects during food technology communication. For example, the type (e.g. whether solely benefit or risk information, or balanced information is provided) and order (i.e., the sequence of information presented) of information are found to influence consumers' attitudes towards various food technologies, such as irradiation (Fox, Hayes and Shogren 2002), biotechnology (Lusk et al. 2004), and nanotechnology (Roosen et al. 2011). Most studies develop their own sets of information on food technologies so that informational impacts can be identified by allocating participants into different information treatments. However, most if not all, prior research uses information treatments written with a logical-scientific language, rather than the narrative format, with which consumers may be more familiar and most likely to encounter in real-life settings when seeking information about a new food technology.

The benefits of using narratives to communicate science to laypeople, have been demonstrated in other areas such as science education and health communication. Compared with the traditional logical-scientific information, narratives (stories) are found to be easier to comprehend, more interesting, engaging and persuasive (Avraamidou and Osborne 2009; Dahlstrom 2014). Story-like materials are more efficient than traditional logical-scientific information when communicating environmental risk (Golding, Krimsky and Plough 1992), vaccination risk (Betsch et al. 2011), and reducing resistance to cancer prevention behaviours (Kreuter et al. 2007).

This study contributes to the existing literature on consumer acceptance of food technologies in three ways. First, it provides a more nuanced understanding of information framing effects by exploring the influences of using a unique information format – narratives – to communicate food biotechnology with non-expert consumers. Second, this study develops logical-scientific and narrative information about biotechnology and provides the information to a representative sample of Canadian consumers under different conditions. The logical-scientific information was written in the scientific style of the passive voice with generalized and impersonal language. In contrast, the narrative information was written in a more lively and vivid personal style. As such, this study allows us to directly compare the effects of using these two distinct information formats to communicate about biotechnology with consumers. Finally, while many previous consumer studies focus on the productivity or environmental benefits of biotechnology (e.g., reduction in pesticide use), this study aims at understanding consumer responses to biotechnology that enhances food attributes with a direct consumer benefit.

This paper is organized as follows. Section 2 provides a review of studies on information framing effects and narrative communication, which inform the current study and outlines two testable hypotheses related to information framing. Data on consumers' attitudes and food choices are collected from an extensive online survey. Section 3 describes the design of the survey, including the development of logical-scientific and narrative information treatments about biotechnology for this study. Section 4 specifies the choice models used to examine consumer choice behaviours. The estimation results are presented in section 5. Section 6 summarizes and concludes.

2. Narrative Communication

Insights from behavioural economics and psychology suggest that individuals are boundedly rational, with limited cognitive capacities when processing complex information (Kahneman and Tversky 1979; Simon 1955). As such, how information is framed and presented to audiences matters in shaping attitudes and behaviours. Information framing effect is the cognitive bias identified by Tversky and Kahneman (1981) in their seminal work showing that changing the framing of decision problems (e.g., whether the probabilities and outcomes are presented in terms of gains or losses) can shift individuals' decisions. Empirical studies of public acceptance of novel food technologies also support the existence of a framing effect, i.e., how benefit and risk information about a certain novel food technology is communicated with the public matters for its acceptance among the public.

A body of empirical studies has suggested that information plays a significant role in perceptions and choice behaviours. For example, the type (e.g. whether solely benefit or risk information, or balanced information is provided), order (i.e., the sequence of information presented), and the source credibility (e.g., government, food industry, scientists) of information all influence attitudes towards novel food technologies (Fox et al. 2002; Lusk et al. 2004; Roosen et al. 2011).

It is not uncommon for participants in a survey or experimental study to be exposed to 'new' information about food technologies prepared by researchers. In these studies, unbiased information was purposefully developed to reflect the best available scientific knowledge and facts and written in a logical-scientific language to appear scientific and professional. However, the information format and language adopted in previous studies are very different than that with which most consumers are familiar.

In real life, consumers get most of their information about new food technologies from mass or social media sources such as television and the Internet (Dahlstrom 2014). Some efforts have been made to understand the impact of media frames on consumers' perceptions. Images of science and technology are generally portrayed as negative by the media, in particular, the sensationalized narratives in television often distort science and inhibit public understanding (Nisbet et al. 2002). The negative frames of biotechnology dominating mass and/or social media have been identified as an important component of public opposition to agricultural biotechnology (Marks and Kalaitzandonakes 2001; McCluskey and Swinnen 2004; Nisbet et al. 2002).

Of particular interest here is the frame used by media content when describing science and technology. A major characteristic of media content is the use of narratives (i.e. stories), as journalists have to balance their dual goals of reporting accurate information while attracting their target audiences' attention (Dahlstrom 2014). The principal practice for developing science news is to personify abstract scientific concepts for dramatic storytelling, and other aspects of information such as accuracy are often ignored (Dahlstrom 2014). To communicate science to the public, the media adopts a different frame than scientific researchers whose objective is to provide accurate rather than attractive messages. Such divergence of information framing about new food technology inspires this study. Science research underscores the importance of accuracy and scientific rigor during its data collection, experiment implementation, and results interpretation. However, the logical-scientific information is often abstract, technical and 'cold' when communicating to some non-expert audiences such as consumers. By contrast, narratives or stories of science communication are more accessible (i.e., via media contents) and using the language laypeople are more familiar with.

Narrative has been defined as a distinctive communication format, however, there exists no such definition of narrative that is universally accepted by scholars as it can take various forms. Dahlstrom (2014, p.13614) provides a fairly standard definition of narrative communication, which is "a particular structure that describes the cause-and-effect relationships between events that take place over a particular time period that impact particular characters". As such, the three essential factors – causality, temporality, and character – determine the narrativity of the information. Examples of narratives include news stories, anecdotes, entertainment television programs and interpersonal conversations (Dahlstrom 2014). This study is mostly concerned with using written stories to communicate new food biotechnology with consumers, thus the narrativity of the message is reflected by the character (a mom with two children), temporality (some past time, i.e., last week, when the family tried out a new apple variety), and causality (the story depicting how this family encountered the new apple variety produced by biotechnology and what their reactions are to this apple).

Narratives represent the default mode of human interaction and make up most daily conversations. Thus, people are more familiar with this type of communication and feel more comfortable when receiving communication about complex issues. By contrast, as an alternative text genre, logical-scientific information usually involves explaining abstract concepts or propositions using vocabulary and an expository structure with which people have less experience. Therefore, narratives are more likely to activate certain emotional and cognitive effects that logical-scientific information are unable to provoke, and hence have profound influences on beliefs and real-world decisions.

The differences between narrative and logical-scientific communication are rooted in dual cognitive systems. Behavioural economists and psychologists point out that humans possess two systems of cognitive reasoning, one is affective, intuitive, and fast, while the other, deliberative, logical, and slow (Chaiken 1980; Kahneman 2011). Information framed in logical-scientific and narrative formats is likely to engage different cognitive pathways. For example, encoding science-based arguments requires the systematic and logical pathway, whereas encoding situation-based exemplars requires the affective and narrative pathway (Dahlstrom 2014).

Despite the merits of narrative communication, this information format has been ignored by studies on acceptance of food technologies. This study aims to fill this gap by investigating whether a narrative effect exists when communicating agricultural biotechnology with consumers. Based on the preceding review of narrative communication, two hypotheses are proposed.

H_1: Information communicated in different formats will induce different degrees of attitudinal changes.

Respondents were asked to evaluate food biotechnology both before and after being exposed to information shown in different formats. For example, respondents indicated whether they think making 'a single precise change to a plant's existing genes' (i.e., gene editing technology) when producing crops or foods is natural, ethical, and safe. After reading logical-scientific or narrative information about biotechnology, respondents assessed the gene editing technique again by answering a set of similar rating questions. As such, we are able to measure how attitudes towards gene editing change within each information condition. We expect that, compared with logical-scientific information, narratives will generate greater attitudinal changes, as they are more persuasive and easier to comprehend.

H_2: Information provided in different formats will have different impacts on preferences for and valuations of novel food traits and technologies.

Respondents made a set of choices about sliced apple products in a choice experiment, which allows us to examine their preferences for different novel food traits (i.e., non-browning and antioxidant-enhanced apple slices) and technologies (gene editing, genetic modification, and edible coating). As the information developed in this study is a 'one-sided' statement emphasizing the benefits of biotechnology, we expect that narratives will generate stronger preferences for novel technologies, compared with logical-scientific information.

3. Survey Method

Consumer data for this study were collected from a nationwide online survey of 804 Canadian adults in the summer of 2016. The average time spent to complete the survey was approximately 40 minutes. As a means to incentivize participation, respondents could enter into a draw to win one of two prizes of $500 once they completed the survey. To assure the quality of data, we exclude responses from participants who sped through the survey by finishing it within less than 15 minutes and/or spending less than 20 seconds on reading the information treatments, as the information impacts are the main focus of this study. Responses were also removed if a large number of straight-lining answers were identified. In the choice experiment, respondents were asked to choose between a set of pre-packaged apple slices, thus non-consumers of apple products were excluded from the study. As a result, the final sample set contains 697 respondents. Table 1 summarize respondents' characteristics within the final data set.

Table 1 Characteristics of Respondents

Variable	Definition	Survey[a]	2011 Census of Canada
Gender	1 if male; 0 if female	0.47	0.49
Age	Age in years	55	48[b]
Education	Highest level of educational attainment: 1 if high school or less; 2 if trades certificate; 3 if college diploma; 4 if university degree; 5 if Master's degree or higher	3.46	2.31
Income	Annual combined household income before taxes: 1 if CAD$29,999 and under; 2 if CAD$30,000 to CAD$49,999 3 if CAD$50,000 to CAD$79,999; 4 if CAD$80,000 to CAD$124,999; 5 if CAD$125,000 and over	3.43	2.90
BC	1 if reside in British Columbia; 0 otherwise	0.14	0.13
ON	1 if reside in Ontario; 0 otherwise	0.38	0.38
QC	1 if reside in Quebec; 0 otherwise	0.22	0.24
Pra	1 if reside in Prairie provinces, i.e., Alberta, Manitoba, Saskatchewan; 0 otherwise	0.17	0.18
Rest	1 if reside in other Canadian provinces or territories; 0 otherwise	0.09	0.07

Notes: a. Mean values based on sample size N=697. b. Mean age of Canadian adults only, those aged 18 or above.

The final sample is reasonably representative of the Canadian population with respondents from across Canada. The sample has a somewhat higher education level and higher incomes relative to national averages, which is common in online data collection (Szolnoki and Hoffmann 2013). The mean sample age is 55, higher than that of Canadian adults, which is potentially due to the length of the survey (i.e., approximately 40 minutes to complete) and that only the primary grocery shoppers in households are allowed to participate in the study.

The central aim of this study is to examine the effects of different information formats on attitudes towards food biotechnology. As such, information was deliberately developed in different formats and each respondent was randomly assigned to one of these information treatments. Information was developed in either a logical-scientific or a narrative format to introduce to respondents how novel food technologies (i.e., gene editing, genetic modification, and a commonly used food processing technique named edible coating) work differently to achieve the consumer-oriented apple characteristics (i.e., non-browning and antioxidant-enhanced apple slices).

The inclusion of the non-browning novel apple attribute is inspired by the recent approval of the Arctic Apple in Canada and the US, which is a genetically modified apple that resists browning as it contains lower levels of enzymes that cause browning. The non-browning trait was introduced to Arctic Apple by the RNA-interference technique, which silences the gene expression of enzymes that makes apples turn brown (Okanagan Specialty Fruits 2013). In addition, as health has been rated as an important motive for food consumption (Renner et al. 2012), we would like to understand how consumers value the healthfulness of a snackable pre-sliced apple product. In this study, respondents were told that the level of health-promoting dietary antioxidants (e.g., Vitamin C) in sliced apples can be enhanced by using food technologies.

Gene editing (a.k.a. CRISPR-Cas9) is a "game-changing" biotech tool that offers dramatic advances in the ease, precision and speed of genetic improvements. Unlike genetic modification, which often involves inserting genes from other species into the plants at random positions to drive the desired gene expression, gene editing can precisely target at the gene location and make the desired changes within existing genes (Ledford 2015). Previous studies suggested that plant breeding methods that do not involve introducing foreign genes is typically preferred than otherwise (Colson, Huffman and Rousu 2011; Hudson, Caplanova and Novak 2015). However, it is still an open question as to whether consumers can differentiate between these two particular biotechnologies. For this reason, we develop information describing how gene editing works differently from genetic modification.

The 'logical-scientific' information was developed based on factual scientific knowledge about agricultural biotechnology. The information was synthesized from resources such as peer-reviewed science journals (e.g., Nature), and reports available from government institutions regulating biotechnology (e.g., Health Canada and the Canadian Food Inspection Agency). The information was deliberately written in a scientific language and plain tone, purposely avoiding any metaphorical descriptions. The specific wordings and layouts adopted in the logical-scientific format thus mimic those appearing in the rigorous scientific reports. We attribute the same logical-scientific information to two different sources: a government institution responsible for biotechnology regulation, 'Health Canada'; and a community of distinguished scientists, the 'Academy of Science | The Royal Society of Canada'.

The 'narrative' information treatment aims to provide respondents with similar information as found in the 'logical-scientific' condition, however, was written in a distinctly different format. The development of narrative information relies on a blog article written by Emily Waltz, a science journalist specializing in writing science stories (Waltz 2015). In the blog post, she shared her experience with Arctic apples by doing a home experiment with her children. They put the Arctic apples through a set of tests, such as slicing, making apple smoothies in a blender, and bruising apples by banging a backpack containing apples on the porch, and the article explains that the family found the Arctic apples outperformed conventional grocery apples in terms of being resistant to browning. On the basis of her story, we developed the narrative information, which depicts a similar set of home tests to explain how a non-browning apple would perform. In addition, we explain how gene editing and genetic modification differ in introducing a novel apple attribute using vivid language. For example, the mechanism of gene editing technique was compared to the find-and-replace function on a computer. We attribute the same narrative information to two different sources: a regular consumer who reports her experience with the new apple varieties in a blog post; and a science journalist who writes for a Canadian newspaper The Globe and Mail.

To compare the differential effects of information formats, we made efforts in assuring the same information content was conveyed in both formats, which describes each novel food technology and explains how they differ from each other in introducing novel apple characteristics. Also, we maintained a comparable length and layout of both information formats. Both information formats were reviewed by a small pilot group in a pre-test of the survey.

Respondents assigned to the 'logical-scientific' and 'narrative' conditions were forced to read the information provided by random allocation. However, in the 'self-selection' condition, respondents were allowed to select one information they prefer to read from the four available options. Respondents in the self-selection condition were initially presented with only the titles and sources of four information options, and allowed access to only one information depending on which they chose from the list of titles and sources.

The sample was divided into four information conditions (i.e., a between-subject design): 'no additional information (control)', 'logical-scientific', 'narrative', and 'self-selection' condition. The number of respondents assigned to each information condition and sources in the final sample set is summarized in Figure 1.

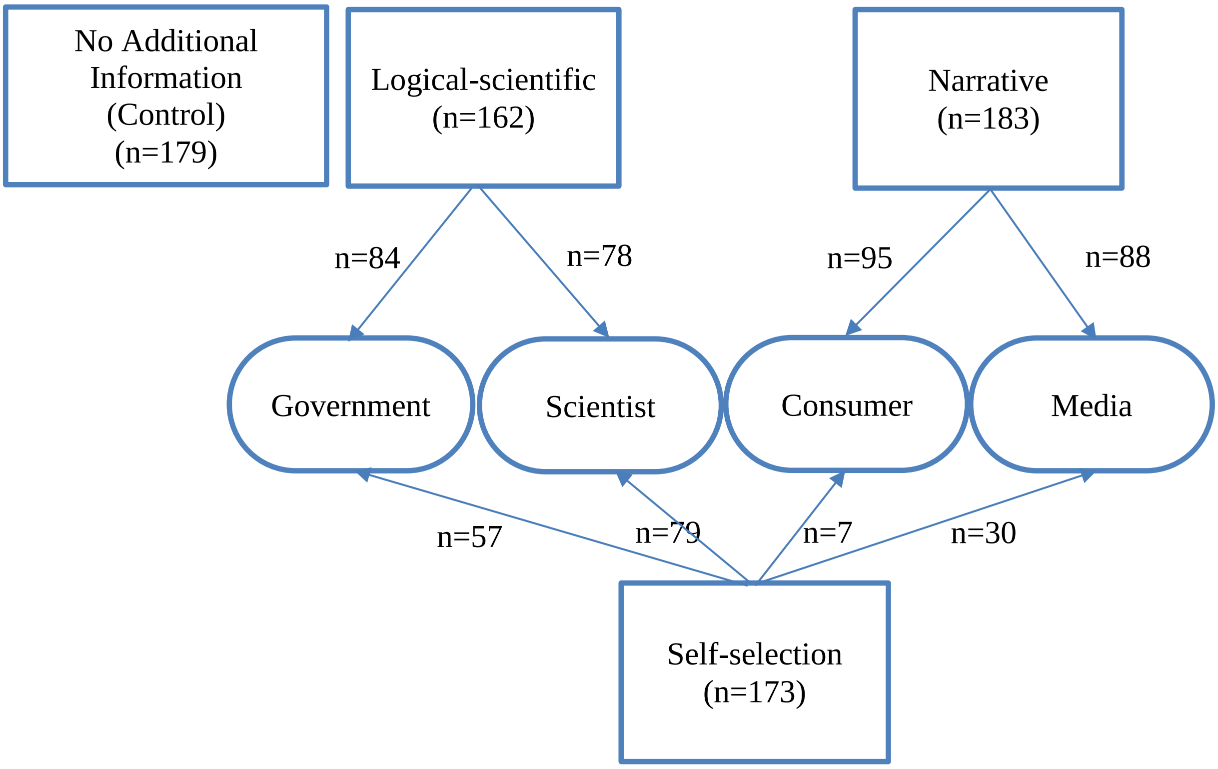

Figure 1 Allocation of Respondents to Information Conditions

Except for those assigned to the 'no additional information (control)' condition, each respondent was passively presented with or actively chose a piece of information about biotechnology shown in either a logical-scientific or a narrative format. This between-subject design allows us to explore the information framing effects, especially examining whether different information formats, logical-scientific vs. narrative, can yield differing food technology attitudes and choice behaviours.

Respondents were then asked to make a series of food choices in a discrete choice experiment. A choice experiment is a quantitative tool to elicit preferences for different (food) attributes by asking people to select the most preferred (food) choice from a set of hypothetical alternatives that are experimentally designed. By observing respondents' choice behaviours, we are able to investigate how alternative information formats can have different impacts on their preferences for novel food characteristics and technologies.

The experiment presented respondents with three alternatives of 500g pre-packaged apple slices with varying characteristics: (1) *appearance* of apple slices, apples can turn brown in minutes after being sliced or resist browning for a long time; (2) *health benefit*, sliced apples are enhanced with higher levels of dietary antioxidants like Vitamin C or contain only a regular amount of antioxidants; (3) *production method*, the aforementioned two novel apple characteristics can be introduced through plant breeding methods (gene editing or genetic modification) or through a food processing method (edible coating). Apples produced by conventional methods will not possess any of those novel characteristics; and (4) the retail *price* for a 500g bag of apple slices. See Table 2 for the apple attributes and their levels included in this study and Table 3 for an example of a choice set presented to respondents.

Table 2 Attributes and Levels in Choice Experiment

Attribute	Levels			
Appearance	Non-browning	Slices turn brown		
Health Benefit	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants		
Production Method	Gene editing	Genetic modification	Edible coating	Conventional
Price	\$3.69	\$4.29	\$4.89	

Table 3 An Example of a Choice Set

Imagine that you are actually buying a 500g bag of apple slices in a real grocery store. If you were able to select from the following options, which one would you buy?

	A	**B**	**C**	**D**
Appearance	Non-browning	Slices turn brown	Slices turn brown	I would not buy any of these products
Health Benefit	Not enhanced with antioxidants	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants	
Production Method	Genetic modification	Gene editing	Conventional	
Price	$4.29	$4.89	$3.69	
I would choose…	☐	☑	☐	☐

A partial constant design was used in developing the choice experiment. That is, each choice set consists of two alternatives with consumer-oriented apple benefits introduced by plant breeding or food processing technologies, one conventional alternative without any additional benefits, and one no-purchase option. This design is 'partially constant' in nature due to the fact that the first two alternatives are always presented with apple benefits and novel technologies, while the third alternative is the conventional option associated with no novel attribute levels and only the price levels are allowed to vary.

A *D-efficient* experimental design was used to generate 36 choice sets, which were further blocked into 6 blocks. Each participant was randomly assigned into a block, and answered 6 choice questions. In each choice situation, respondents were asked to choose between three alternatives or chose to buy nothing. Therefore, a total of 4182 choice observations were gathered from a final sample of 697 respondents.

4. Choice Model Specification

Choice data are analysed using a standard multinomial logit (MNL) and a random parameter logit (RPL) models. In the standard MNL model, the effects of information format on preferences are captured via interacting the attribute variables with information conditions as shown in the equation (1).

$$U_{nsj} = \beta_{NB} \times NB_{nsj} + \beta_{AE} \times AE_{nsj} + \big(\beta_{GE} + \gamma_{GE\times No} No_n + \gamma_{GE\times Self\_logic} Self\_Logic_n + \gamma_{GE\times Narr} Narr_n\big) \times GE_{nsj} + \big(\beta_{GM} + \gamma_{GM\times No} No_n + \gamma_{GM\times Self\_logic} Self\_Logic_n + \gamma_{GM\times Narr} Narr_n\big) \times GM_{nsj} + \beta_{EC} \times EC_{nsj} + \beta_{PRI} \times PRI_{nsj} + \varepsilon_{nsj}, \qquad j = 1, 2, 3$$

$$U_{nsj} = \beta_j + \varepsilon_{nsj}, \qquad j = 4 \qquad (1)$$

where β_{NB}, β_{AE}, β_{GE}, β_{GM}, β_{EC}, and β_{PRI} are the preference parameters (marginal (dis)utilities) of the attributes non-browning (*NB*), antioxidant-enhanced (*AE*), gene editing (*GE*), genetic modification (*GM*), edible coating (*EC*) and price (*PRI*). β_j is the alternative specific constant (ASC). $\gamma_{GE\times No}$, $\gamma_{GE\times Self\_logic}$, $\gamma_{GE\times Narr}$, $\gamma_{GM\times No}$, $\gamma_{GM\times Self\_logic}$, $\gamma_{GM\times Narr}$ are marginal effects of interaction terms, which capture the effects of different information formats – 'no information' (*No*), 'self-select logic' (*Self-Logic*), 'narrative' (*Narr*) – on the preferences for attributes *GE* and *GM*, compared to the reference 'forced logic' information condition (*Forced_Logic*). ε_{nsj} is assumed to be i.i.d. EV1 with mean of $\gamma \approx 0.5772$ and variance of $\pi^2/6$.

In RPL, we control for the effects of information on preference parameters by making the means of the preference parameters a function of information-condition-specific covariates. By doing this, we can investigate the effects of different information formats on respondents' preferences (tastes) while allowing for unobserved preference heterogeneity. As shown in equation (2) below,

$$U_{nsj} = \beta_{n,NB} \times NB_{nsj} + \beta_{n,AE} \times AE_{nsj} + \beta_{n,GE} \times GE_{nsj} + \beta_{n,GM} \times GM_{nsj} + \beta_{n,EC} \times EC_{nsj} + \beta_{n,PRI} \times PRI_{nsj} + \varepsilon_{nsj}, \qquad j = 1,2,3$$

$$U_{nsj} = \beta_j + \varepsilon_{nsj}, \qquad j = 4 \qquad (2)$$

the individual-specific random parameters are defined as functions of information formats, NO_n, $Self\_Logic_n$ and $Narr_n$.

$$\beta_{nk} = \beta_k + \Delta_{k\times No} No_n + \Delta_{k\times Self\_logic} Self\_Logic_n + \Delta_{k\times Narr} Narr_n + \sigma_k v_{nk}, \quad k = GE, GM$$

$$\beta_{nk} = \beta_k + \sigma_k v_{nk}, \qquad k = NB, AE, EC, PRI \qquad (3)$$

where β_k is the fixed portion of mean preference for attribute k, which stays constant over individuals. $\Delta_{k\times No}No_n$, $\Delta_{k\times Self\_logic}Self\_Logic_n$ and $\Delta_{k\times Narr}Narr_n$ capture the observed heterogeneity around the mean of random parameters. v_{nk} is the random or unobserved component of preference, i.e., a random variable with zero mean and a known variance, thus it captures any unobserved preference heterogeneity. In this study, we assume the random parameters of all non-price attributes are standard normally distributed, and the price coefficient follows a constrained triangular distribution to preserve a behaviourally plausible (i.e., negative) sign over the entire sampled population.

$$v_{nk} \sim N[0,1] \qquad for\ k = NB, AE, GE, GM, EC$$

$$v_{nk} \sim triangle[-1,1]\ and\ \sigma_k = \beta_k \qquad for\ k = PRI \qquad (4)$$

Based on the preceding specifications, the simulated log-likelihood function for the RPL model is:

$$SLL(\beta_n|\Omega) = \sum_n l\,n\left[\frac{1}{R}\sum_{r=1}^{R}\prod_s\prod_i L_{nsi}(\beta_n^r)^{y_{nsi}}\right]$$

$$\text{where} \quad L_{nsi}(\beta_n^r) = \frac{exp\left[x'_{nsi}\left(\beta + \Delta_{No}No_n + \Delta_{Self\_logic}Self\_Logic_n + \Delta_{Narr}Narr_n + \sigma v_n^r\right)\right]}{\sum_j exp\left[x'_{nsj}\left(\beta + \Delta_{No}No_n + \Delta_{Self\_logic}Self\_Logic_n + \Delta_{Narr}Narr_n + \sigma v_n^r\right)\right]} \quad (5)$$

5. Results and Discussion

This section presents results of two sets of analyses. Section 5.1 examines whether different information frames would generate differing attitudinal changes towards biotechnology. Section 5.2 investigates whether information and its formats have influences on food choice behaviours by estimating two choice models.

5.1 Attitudinal Analyses

To examine the effects of information format on attitudes towards novel food technologies, a series of attitudinal questions were asked to respondents both before and after information provision. Before providing any detailed information about the gene editing technology (even the name of the technology, ‘gene editing’, was not yet mentioned), respondents were asked to indicate whether they think making ‘a single precise change to a plant’s existing genes’ in producing crops or foods is *natural*, *ethical*, and *safe* (1=not at all, 6=completely). Responses to these three questions were combined to construct a single reliable index, '*GE_prior*' (Cronbach's $\alpha = 0.87$), indicating attitudes towards gene editing *before* information provision.

Then, respondents were randomly assigned to one of four information conditions, in which they were provided with detailed information about novel food technologies, such as how gene editing works differently than genetic modification to achieve the non-browning and antioxidant-enhanced apple characteristics. After reading the information and making six food choices in the choice experiment, each respondent was then asked to answer eleven questions about what they think about using gene editing technology in food production. Based on their responses, a reliable index, '*GE_post*' (Cronbach's $\alpha = 0.92$), is constructed to reflect attitudes towards gene editing *after* information provision. The change in attitude is measured by the difference between attitudes before and after information exposure, i.e., $GE\_diff = GE\_post - GE\_prior$.

To test our first hypothesis (H_1) that different information formats will generate differing degrees of attitudinal changes, we first investigate whether gene editing attitude prior to information provision is equal to that after the information provision. Results are summarized in Table 4.

Table 4 Change in Attitudes towards Gene Editing across Information Format

Information Condition	Observations	GE_prior	GE_post	GE_diff
No Information	179	3.086 (0.104)[a]	3.368 (0.083)	0.283 (0.074)***[b]
Forced Logic	162	3.062 (0.111)	3.436 (0.096)	0.374 (0.085)***
Forced Narrative	183	3.056 (0.104)	3.631 (0.085)	0.574 (0.072)***
Self-select Logic	136	3.208 (0.122)	3.602 (0.105)	0.393 (0.082)***
Self-select Narrative	37	2.730 (0.239)	3.366 (0.201)	0.636 (0.172)***

Notes: a. Numbers in parentheses are standard errors of the mean. b. *** indicates statistically and significantly different from 0 at 1% confidence level.

The test of equality-of-means before and after information provision is a within-subject test, thus any individual-specific variables are not included (Lusk et al. 2004). Results of both parametric paired *t*-tests and non-parametric Wilcoxon singed-rank tests suggest that respondents' attitudes towards gene editing technology are statistically and significantly different (i.e., at a 1% level) before and after information provision for all information conditions. As the information pieces developed for this study are 'one-sided' statement nature, it is unsurprising to observe that attitudes towards gene editing improved after information exposure.

We also note that for respondents assigned to the 'no additional information' condition, their attitudes also statistically improved without being exposed to detailed information about novel food technologies. This attitude change could be a result of participating in the choice experiment, in which respondents were asked to make six food choices from a set of experimentally designed hypothetical food products varying in characteristics and production methods. Even though purposely no additional detailed information about gene editing food technology was presented during the choice experiment, to facilitate the choice tasks, respondents did receive a short instruction before entering the choice experiment, in which they were introduced to how alternative products vary in terms of appearance, health benefit, production method, and price. A 'one-sentence' description of gene editing appeared in the instruction (i.e., *gene editing: make changes to an apple's existing genes to enhance or suppress the gene's activities*) together with a description of genetic modification (i.e., *genetic modification: insert new genes from other species into apples*). It is possible that respondents compared the two technologies during the choice experiment, and hence responded to attitudinal questions on gene editing (i.e., GE_post) more favourably even without being presented with additional detailed information.

To control for the effect of doing the choice experiment (i.e., accounting for the attitudinal change in '*No Information*' condition), we use the 'difference in differences' test to compare the attitudinal changes across information conditions. We found that narratives (i.e., '*Forced Narrative*') tend to generate greater attitudinal changes compared with the logical-scientific information (i.e., '*Forced Logic*')[1]. As such, H_1 is supported.

To confirm this finding, we also use a regression-based method. We simply estimate separate models for each information condition, and test whether parameters differ across conditions. In the linear regression model, a set of exogenous variables are included to hold constant any differences in subject-specific effects across information condition.

[1] Results of 'difference in differences (DID)' estimation indicate that the values of *GE_diff* differ significantly at a 10% level when comparing between conditions of '*Forced Narrative*' vs. '*No Information*', '*Forced Narrative*' vs. '*Forced Logic*', and '*Self-select Narrative*' vs. '*No Information*'. While *GE_diff* values are not significantly different across all other conditions.

$$GE\_post = \beta_{0,k} + \beta_{1,k} GE\_prior + \beta_{2,k} Sci + \beta_{3,k} Bio\_neutral + \beta_{4,k} Bio\_postive + \beta_{5,k} Age + \beta_{6,k} University \quad (6)$$

Attitudes toward gene editing after information provision (GE_post) is expected to be influenced by the attitude toward gene editing before information exposure (GE_prior), the attitude on science and technology in general (Sci), perception of risks and benefits of agricultural biotechnology ($Bio\_neutral$, $Bio\_postive$) and demographics (Age, $University$). The parameters for each independent variable ($\beta_1 - \beta_6$), as well as the intercept (β_0), are allowed to vary by information condition $k =$ 'no additional information', 'forced logic', 'self-select logic', 'narrative'.

"Narrative" condition is constructed by pooling together the responses in both "Forced_Narr" and "Self_Narr" conditions. We pooled narrative conditions for two reasons. First, we suspect that the number of respondents who voluntarily selected narrative information (n=37) is too small to generate any statistically meaningful results. Second, we were unable to identify any significant differences between the "Forced_Narr" and "Self_Narr" conditions in terms of responses of information quality assessment, changes of attitudes towards biotechnology, as well as preferences for food technologies as revealed in choice analysis. That is, the voluntary information access or self-selection of narratives has no additional impact on attitudes and behaviours, compared with narratives presented directly to respondents. Table 5 reports the estimation results.

Table 5 Effect of Prior Attitude and Demographics on Post Attitude by Information Format

	No Information		**Forced Logic**		**Self-select Logic**		**Narrative**	
	Par.	*p*-value	Par.	*p*-value	Par.	*p*-value	Par.	*p*-value
Intercept	1.293***	0.000	0.677*	0.099	0.512	0.253	0.559*	0.051
GE_prior	0.427***	0.000	0.379***	0.000	0.496***	0.000	0.452***	0.000
Sci	0.090*	0.074	0.130**	0.049	0.237***	0.001	0.136***	0.002
Bio_neutral	0.013	0.933	0.660***	0.001	0.806***	0.000	0.491***	0.000
Bio_positive	0.708***	0.000	1.065***	0.000	0.670***	0.001	0.817***	0.000
Age	0.002	0.614	0.008	0.118	−0.004	0.487	0.011***	0.002
University	−0.183*	0.098	−0.174	0.189	−0.089	0.532	−0.169*	0.084
# of Obs.	176		158		127		214	
R^2	0.606		0.588		0.650		0.652	

Notes: 1. Dependent variable is *GE_post*. 2. *, **, *** designates statistical significance at the 10%, 5%, 1%, respectively.

We find that attitudes toward gene editing prior to information exposure (*GE_prior*) significantly influences the attitude after information exposure. In four information treatments, a higher (more positive) prior gene editing attitude is associated with a higher post gene editing attitude. A similar result is found for attitudes towards agricultural biotechnology in general (*Bio_positive*). Individuals who believe the benefits of biotechnology outweigh its risks tend to react more favourably to the information on gene editing than those who believe biotechnology's risks are greater than its benefits.

In the regression, all parameters of independent variables, including the intercept, are allowed to vary by information condition. A global test is needed to test the joint hypotheses that the estimated parameters are equivalent across treatments. The likelihood ratio test rejects the null hypothesis of 'equality-of-coefficients' across information treatments ($\chi^2_{21} = 42.65$, *p*= 0.0035), as such we conclude that at least one estimated parameter differs by information condition (i.e., which could be any of the independent variable effects, the intercept term, or a combination of these). For example, the general attitude toward science and technology (*Sci*) is shown to have a statistically significant impact on gene editing attitude in the 'self-select logic' and 'narrative' condition, whereas its impact is only marginally significant in the 'no information' and 'forced logic' condition. That is, the effects of included variables differ by information treatments.

In sum, analyses on attitudinal changes support our first hypothesis (H_1) that information communicated in different formats induces differing degrees of changes in attitudes towards gene editing technology. The detailed information developed in the study is one-sided and hence significantly improves attitudes towards gene editing technology, however, the extent to which attitude is changed varies by information format. Narratives tend to generate greater levels of changes in attitudes (positively) towards gene editing, compared with logical-scientific information format. Results from the simple linear regression also suggest that the estimated parameters differ across information treatments.

5.2 Choice Data Analyses

The choice experiment allows us to test the second hypothesis (H_2) that information framing will influence individuals' choice behaviours. By observing respondents' choices in the choice experiment, we are able to understand how respondents make trade-offs between different novel food traits (i.e., non-browning and antioxidant-enhanced apple slices) and technologies (gene editing, genetic modification, and edible coating).

Two sets of choice models are estimated, a multinomial logit model (MNL) and a random parameter logit model (RPL) that allows for unobserved heterogeneity in preferences. Both models are estimated in Nlogit 6 (Econometric Software Inc). The MNL model is estimated by maximum likelihood method, and the RPL model is estimated by maximum simulated likelihood with 200 Halton draws. Table 6 reports the estimation results.

Table 6 Choice Model Results

	MNL		RPL	
			Random Parameters	
	Coeff.	Std.Err.	Coeff.	Std.Err.
Non-browning	0.700***	0.070	0.800***	0.180
Antioxidants-enhanced	0.149**	0.065	-0.067	0.159
Gene editing	-1.108***	0.127	-1.599***	0.302
Genetic modification	-1.616***	0.142	-2.882***	0.346
Edible coating	-1.368***	0.097	-2.333***	0.202
Price	-0.657***	0.038	-1.962***	0.073
			Non-random Parameters	
No-purchase	-3.370***	0.167	-9.754***	0.350
Mean Shifter				
Gene editing: no information	-0.326**	0.142	-0.856**	0.367
Gene editing: self-select logical-scientific information	0.214	0.144	0.356	0.403
Gene editing: narrative information	0.496***	0.127	0.903***	0.341
Genetic modification: no information	-0.266	0.164	-0.506	0.402
Genetic modification: self-select logical-scientific information	0.490***	0.162	1.259***	0.405
Genetic modification: narrative information	0.326**	0.149	0.813**	0.372
Standard Deviation				
$\sigma_{non-bronwing}$			3.221***	0.178
$\sigma_{antioxidants-enhanced}$			2.684***	0.166
$\sigma_{gene\ editing}$			1.637***	0.225
$\sigma_{genetic\ modification}$			1.516***	0.217
$\sigma_{edible\ coating}$			2.086***	0.218
σ_{price}			1.962***	0.073
Model Characteristics				
Log likelihood	-5348.156		-3758.611	
Pseudo R^2	0.078		0.352	
AIC/n	2.564		1.806	
BIC/n	2.584		1.833	
# of Observations	4182		4182	
# of Parameters	13		19	

Notes: 1. Number of respondents = 697. 2. Number of choices observed = 4182. 3. *, **, *** designates statistical significance at the 10%, 5%, 1%, respectively.

According to the likelihood ratio (*LR*) test, the RPL model allowing for unobserved heterogeneity of preferences significantly improves the model fit, as indicated by the highly significant increase in the log-likelihood values ($\chi^2(6)=16.812$, $p<0.01$). That is, the RPL model outperforms the MNL model. The statistical significance of all standard deviation estimates indicates that there is substantial unobserved preference heterogeneity with respect to all attribute parameters.

To understand individuals' preferences for different apple characteristics and food technologies included in the choice experiment, we calculate the marginal utilities for each attribute. Due to the existence of interaction terms, the marginal utilities are calculated by averaging over the sampled population. For example, the marginal utility of *GE* for individual *n* is calculated as:

$$\frac{\partial U}{\partial GE} = \beta_{GE} + \gamma_{GE\times No} No_n + \gamma_{GE\times Self\_Logic} Self\_Logic_n + \gamma_{GE\times Narr} Narr_n$$

$$= -1.108 - 0.326 \times No_n + 0.214 \times Self\_Logic_n + 0.496 \times Narr_n \qquad (7)$$

The average marginal utility of *GE* is then obtained by averaging equation (7) over the entire sample. Table 7 summarizes the marginal utility estimates for the MNL and RPL models.

Table 7 Marginal Utilities for Individual Attributes

	MNL		RPL	
	Mean	Std. Err.	Mean	Std. Dev.[2]
NB	0.700***	0.070	0.831***	3.217
AE	0.149**	0.065	-0.056	2.700
GE	-0.994***	0.093	-1.478***	1.757
GM	-1.486***	0.099	-2.522***	1.654
EC	-1.368***	0.097	-2.316***	2.074
PRI	-0.657***	0.038	-1.967***	0.803

Notes: 1. In the MNL, to compute the mean marginal utility of an attribute, the expression is computed for each observation in the sample and the average is taken. 2. In the RPL, in order to obtain the mean marginal utility, the population has to be first simulated by taking draws from the normal (for non-price attributes) or one-sided triangular (for price attribute) distributions, then compute the value of the expression for each observation and take the average. 3. *, **, *** designates statistical significance at the 10%, 5%, 1% levels, respectively.

Both models suggest that, on average, apple slices that are non-browning are welcomed by respondents, compared with apples slices that turn brown quickly. The antioxidant-enhanced attribute is only marginally significant (at the 5% level) and positive in the MNL model, but insignificant in the RPL model. A possible reason is that apples are already perceived by consumers as a healthy food choice as they contain high levels of dietary antioxidants.

Both models indicate that all three novel food technologies – gene editing, genetic modification and edible coating – are discounted by respondents compared to the conventional production method, *ceteris paribus*, as indicated by their significant and negative estimates in both models. In addition, among the three novel food technologies, gene editing is the least discounted, followed by edible coating, while genetic modification is the most discounted food technology[3]. As expected, a higher price is associated with a lower utility level.

[2] In the RPL model, the random parameters of all non-price attributes ($v_{n,NB}$, $v_{n,AE}$, $v_{n,GE}$, $v_{n,GM}$, $v_{n,EC}$) are assumed to be standard normally distributed, and the price parameter ($v_{n,PRI}$) follows a constrained triangular distribution. To obtain the mean marginal utility for each attribute (β_k), the population has to be first simulated by taking draws from the normal (for non-price attributes) and one-sided triangular (for price attribute) distributions, then compute the value of the expression for each observation (β_{nk}) and take the average. As such, standard deviations are reported for the RPL model instead of standard errors, which require a bootstrapping approach to compute.

[3] Both models suggest that gene editing is significantly preferred relative to genetic modification at the 1% significance level (Wald test). Preference difference between gene editing and edible coating is also significant at the 1% level, with gene editing preferred relative to edible coating. Edible coating is found to be preferred to genetic modification, however, only at a 10% significance level.

Information formats are significant in affecting preferences for novel food technologies. Recall that respondents were randomly assigned to one information condition, including 'no additional information' (*No*), passively or voluntarily read 'logical-scientific' information about biotechnology (*Forced_Logic* or *Self-Logic*), and passively or voluntarily read 'narrative' information (*Forced_Narr* or *Self-Narr*). These information-condition-specific covariates (*No*, *Forced_Logic*, *Self_Logic*, and *Narr* [4]) entered the choice models through interaction terms (see equations (1) – (3)). For estimation purposes, we set *Forced-Logic* condition as the reference group. As such, we are able to identify any potential effects of information exposure (by comparing *No* with *Forced-Logic*), voluntary information access (by comparing *Self_Logic* with *Forced-Logic*) and the narrative effect (by comparing *Narr* with *Forced-Logic*).

Results indicate that, *ceteris paribus*, compared to the '*Forced_Logic*' information, providing '*No*' information reduces the preference for gene editing; '*Narr*' information induces higher preferences for gene editing; while the '*Self_Logic*' information is not significantly different from the '*Forced_Logic*' information in affecting preferences for gene editing. With respect to the preference for genetic modification, '*Narr*' and '*Self_Logic*' information are both associated with significant and positive estimates, which indicates higher preferences for genetic modification compared to the '*No*' information and '*Forced_Logic*' conditions.

We identified slightly different information effects for gene editing and genetic modification. For both technologies, narratives help to reduce the marginal disutility of food technology compared with the forced logical-scientific information, however, voluntary information access (to logical-scientific information) reduced the marginal disutility only for genetic modification. A possible reason is that consumers are more familiar with genetic modification as the technology has been applied in many crops and food products and they may have been exposed to more information about genetic modification in media outlets. As such, people would value the "freedom" or "autonomy" in information choice when they are allowed to select the information they prefer to read. In contrast,

[4] "*Narr*" condition is constructed by pooling together the "*Forced_Narr*" and "*Self_Narr*" conditions, as the number of respondents in "*Self_Narr*" condition is too small (n=37) to identify statistically significant results. Also, we ran choice models with "*Forced_Narr*" and "*Self_Narr*" conditions both included, however, we were unable to identify any significant differences in their impacts on preferences for food attributes.

gene editing is relatively new to consumers, therefore they have limited information access and are less familiar with it. Value of "freedom" or "autonomy" in information choice becomes less important when people have very little prior knowledge. As such, there is no significant difference between passively reading some new information and voluntarily selecting new information to read. This assumption (i.e., the value of voluntary information access is dependent on levels of prior knowledge or information), however, requires further research to validate.

In sum, analysis of the choice data supports our second hypothesis (H_2) that the same-content information about food biotechnology shown in different formats (logical-scientific vs. narrative) or being accessed by respondents in different manners (forced exposure or voluntary choice) can have differing impacts on preferences for novel food attributes. Results indicate that, compared with logical-scientific information, narratives could help to reduce the marginal disutility associated with food biotechnology. In addition, even when information is shown in the logical-scientific format, voluntary information access could also help to reduce the marginal disutility of food biotechnology.

6. Conclusion

This study compares the effectiveness of logical-scientific vs. narrative information formats in communicating biotechnology to consumers. Even though a number of economic studies exist to explore information framing effects within a food context, none of them have focused on this unique information format, narratives, and examined its impacts in shaping attitudes and behaviours related to new food technologies.

We developed two testable hypotheses. First, due to the easiness to comprehend and the vivid story-like writing style, we assume that narrative information will induce greater attitudinal changes (positively) towards biotechnology, compared with the plain and technical logical-scientific information (H_1). The detailed information developed in the study is one-sided and hence significantly improves attitudes towards gene editing technology, however, the extent to which attitude is changed varies by information format. Results from the simple linear regression of biotechnology attitudes also suggest that the estimated parameters differ across information treatments.

Second, we hypothesize that information frames will have significant influence on choice behaviours related to biotechnology (H_2). Results of both choice models, MNL and RPL, reveal that all three novel food technologies – two plant breeding techniques gene editing and genetic modification, and one food processing method edible coating – are associated with negative marginal utilities. A closer look at the model results further indicates that respondents discount gene editing technology significantly less than genetic modification and edible coating, *ceteris paribus*, which has significant implications for the food industry and regulators. As gene editing and genetic modification appear to be perceived and evaluated differently, informing consumers about how gene edited and genetically modified foods differ could be useful in reducing any opposition towards gene editing.

The novel food traits introduced by food technologies are shown to be welcomed by respondents. Both models suggest that the non-browning and antioxidant-enhanced attributes in pre-packaged sliced apple products are associated with significant and positive marginal utilities, even though strong evidence shows that preference heterogeneity among consumers appears to exist.

Information helps to disseminate factual knowledge about food biotechnology, however, the framing or format of information matters when communicating with consumers. Analysis of choice data reveals that the same-content information about food technology shown in different formats (logical-scientific vs. narrative) or being accessed by respondents in different manners (forced exposure or voluntary choice) has differing impacts on consumers' preferences. Compared with logical-scientific information, narratives could help to reduce the marginal disutility associated with food biotechnology. In addition, even information shown in the logical-scientific format, voluntary information access could also help to reduce the opposition to food biotechnology.

Findings of this paper have a number of implications for policy makers and industry participants. First, information framing around food technology matters during public communication. We find that narratives (stories) developed on the basis of factual and unbiased scientific knowledge help to promote a greater comprehension and engagement of science debate, as narratives were rated by the sampled consumers as easier to comprehend than the logical-scientific information. Also, using narratives to communicate complex scientific knowledge may help promote a particular outcome, since narratives are found to help reduce the opposition to biotechnology. As such, we suggest that, policymakers who aim to inform the public about a complex issue or to promote a particular policy (for instance, the labelling initiatives related to food biotechnology), need to ensure that the language they use in public communication are easily understood and perceived as trustworthy and credible by the lay public.

Also, with the rapid pace of scientific and technological development, it becomes more challenging to communicate with consumers about the potential benefits and risks offered by novel food technologies. Based on our findings, narratives (stories) developed on the basis of unbiased scientific facts could potentially be used as a strong tool to communicate with the non-expert public. The logical-scientific information dissemination style (for instance, scientific journals) is the most appropriate format for communication between scientists, however, this communication strategy is less effective when used in communication between scientists and non-experts, especially when there exist public controversies over science. Therefore, to inform consumer decision-making, those involved in science communication (for instance, plant scientists, food scientists, science outreach, policymakers, and science journalists) may consider using narratives (stories) to communicate complex scientific knowledge or facts with the non-expert public. Science communicators may also be trained to use narratives (as journalists do) to improve their communication with non-expert audiences.

In summary, this study confirms the significance of information framing effects, and contributes to the existing economic literature by investigating the effect of a unique information format to communicate novel food technologies with consumers. We examined whether the same scientific information presented in different formats – logical-scientific vs. narrative – yield differing attitudes and behaviours related to biotechnology. Results reveal significant information framing effects: narratives and voluntary information access both help to reduce opposition to biotechnology, compared with traditional logical-scientific information.

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